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Contribution of Okra (*Abelmoschus esculentus* L. Moench) – Cowpea (*Vigna unguiculata* L. Walp) Intercropping to Productivity of the System in Semi-deciduous Forest Zone of Ghana

Michael Odenkey Quaye[1], Joseph Sarkodie-Addo[2], Agyeman Kennedy[3], Patrick Atta Poku Snr[4] and Clement Gyeabour Kyere[4*]

[1]St. Louis College of Education, Post Office Box 3041, Kumasi, Ghana.
[2]Department of Crop and Soil Science, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.
[3]Center for Scientific and Industrial Research (CSIR), Crop Research Institute, Post Office Box 74, Fumesua, Kumasi, Ghana.
[4]Department of Science Education, Seventh-Day Adventist College of Education, University of Cape Coast, P.O. Box 29, Agona-Ashanti, Ghana.

Authors' contributions

This work was carried out in collaboration among all authors. Authors MAQ and JSA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MAQ and AK managed the analyses of the study. Authors PAPS and CGK managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This study was conducted to assess the growth, yield and cost effectiveness of okra-cowpea intercropping system at the Plantation Section of Faculty of Agriculture, Kwame Nkrumah University of Science and Technology, Kumasi, during the major rainy season of 2017. The okra was planted on 1st May, 2017 and the cowpea introduced at varying planting dates i.e. at the same time, 1, 2, 3 and 4 WAP. Sole okra and cowpea served as control. The experimental plots were

**Corresponding author: Email: kyere.clement@yahoo.com;*

laid out in a randomized complete block design (RCBD) with seven (7) treatments and replicated three (3) times. The data collected were analyzed using the one-way analysis of variance (ANOVA) and the treatment means separated by least significance difference (LSD) at 5% probability. Results showed that time of introduction of the cowpea caused a reduction ($P < 0.05$) in the growth and yield of the component crops. The partial equivalent ratio of cowpea planted at the same time with okra and one week later was greater ($P < 0.05$) than the component okra whiles that of okra was greater than cowpea in 2, 3 and 4 weeks. The Land Equivalent Ratio of all the intercrops was greater than 1 showing that intercropping okra with cowpea was beneficial. The highest Gross Monetary Returns, Land Equivalent Ratio and Monetary Equivalent Ratio of GH₵ 7,039.40, 1.75 and 1.31, respectively were recorded in okra intercropped with cowpea 2 WAP. Okra sown with cowpea at the same time recorded a disadvantage (0.84) in Monetary Equivalent Ratio. To ensure higher yield and economic returns, cowpea could be introduced into okro 2 weeks after planting okro.

Keywords: Intercropping; competition; okra; cowpea; growth and yield.

1. INTRODUCTION

The focus of agricultural research over the years has been on sole or monocropping because relatively, it does not require much planning and management [1]. Odedina et al. [2] reported that more than 70% of food crops produced in tropical Africa come from intercropping. In Ghana, almost all peasant farmers practice mixed cropping or intercropping. In 1960, Ghana's population stood at 6.7 million but it grew a three-fold to 18.7 million in 2000 [3]. This rapid growth in the population and its attendant urbanization and expansion of amenities has consequential effect on crop production [4] particularly; it threatens the availability of land for farming by resource poor farmers.

There is, therefore, the need to increase productivity per unit area hence the need for intercropping. Growing two or more compatible crops on the same piece of land has been found to increase production [5], improve soil fertility [6], guard against total crop failure [7] among other benefits.

In any intercropping system, competition for various resources by the component crops is obvious. The extent of the competition however, is influenced by the type of crop species interacting. Intercropping with legumes is reported to fix nitrogen which ensures positive complementary interaction [8]. Other factors that determine the extent of competition include plant density, the architecture or nature of growth as well as time of planting the component crops. The component crops in an intercropping system may be sown together at the same time or later as decided by the farmer [9]. Varying the planting time of the component crops determines the productivity and extent of competition for growth resources. Osei-Bonsu and Buckles [10] reported for example that sowing mucuna early into maize resulted in reduced maize yield. If the peak demand for resources varies, less competition occurs and greater yield is recorded.

Okra (*Abelmoschus esculentus* L. *Moench*) is a crop which belongs to the family *Malvacea* and is reported to have originated in Africa [11]. It is ranked third in terms of production and consumption after tomato and onion, making it one of the popular vegetables in the tropics and subtropical regions of the world [12]. Okra contains proteins, carbohydrate and vitamin C and hence plays an essential role in the nutrition of humans [13]. Over sixty percent of okra grown in Nigeria and in most parts of sub-tropical Africa is produced under intercropping with other crops [14].

Cowpea has been reported by Sanginga et al. [15] as a crop that forms a component of most farming systems in West Africa, particularly in intercropping. Some varieties can form mat of vegetation to cut-off sunlight from weeds physically by smothering, thereby reducing interference of weeds. They also improve the nutrient status of the soil through the fixing of nitrogen and organic matter accumulation. According to the International Institute of Tropical Agriculture (IITA) [16] cowpea is one of the most essential leguminous crops in the sustainable maintenance of soil fertility. Cowpea is reported to fix about 88 kg N/ha [8] when inoculated with effective rhizobium, up to 155 kg N/ha is fixed. It is estimated that 80 – 90% of the plant's total N requirement is met through this process. Apart from its importance in farming systems, it serves as source of food for man supplying humans with vegetable protein (23 – 30%), minerals such as calcium and iron [17]. The intercropping studies that have been done on cowpea focused primarily on cereals with only a few works done on vegetables. Not much work therefore has been done on vegetable-legume intercrop. In the few studies where vegetable-legume intercrop was investigated, the appropriate time of introducing the intercrop has not been fully investigated. This present work aimed at investigating intercropping by varying the time of introducing cowpea into the okra and evaluating their agro-economic performance.

The objective of the study was to determine the monetary returns and evaluate the performance of okra intercropped with cowpea at varying planting times.

2. MATERIALS AND METHODS

2.1 Experimental Site Description

The study was carried out during the major rainy season i.e. between April and August in 2017 at the Faculty of Agriculture Research Fields, Plantation Section of the Kwame Nkrumah University of Science and Technology in Kumasi. The location lies on 6°43′N, 1°36′W. The research site is in the semi-deciduous forest zone of Ghana. The soil at the experimental site is Ferric Acrisol [18] which belongs to the Kumasi series [19]. The texture of the soil is sandy loam with reddish brown colour. The experiment was conducted on plots which had been used for experimental research on maize, cowpea and soybean in the previous seasons.

The rainfall pattern in the area is bimodal. The major rainy season starts from March and end in July and, a short dry period follow in August. The minor season starts from September to November. The area has a mean minimum and maximum temperature of 21°C and 31°C respectively. The mean annual rainfall of the area is 1727 mm.

2.2 Land Preparation and Planting

The field was disc-ploughed and harrowed after which the field layout was done. Plot sizes measuring 4 m x 4 m were demarcated. 1 m alley was left between the blocks and 1 m between plots. The cowpea seeds used for the study were obtained from the Crops Research Institute (CRI) of the Council for Scientific and Industrial Research (CSIR), Fumesua, Ghana. The variety of the test crop used was "Nyhira". It is one of the determinate varieties developed by Crops Research Institute. The variety of okra used is "Asontem", a local variety of okra. Germination tests of the seeds showed 97% for cowpea and 82% for okra.

Planting of the okra was done on the 1st of May, and cowpea was planted at 1st, 8th, 15th, 22nd and 29th May showing interplanting at one, two, three and four weeks after planting (WAP). The planting spacing for sole okra was 80 cm x 40 cm while the plant population for sole okra was 3.1 plants per meter square. The sole cowpea was sown at a planting distance of 60 cm x 20 cm while plant population for sole cowpea was 10.7 plants per meter square. In the intercrops, the cowpea was sown between the rows of the okra in a 1:1 spatial arrangement. Four seeds of okra and cowpea were sown per hill and thinned to one per stand of okra and two per hill of cowpea 2 weeks later for both crops. The cowpea was planted in a 1:1 spatial arrangement with the okra under the additive series. In the intercrops, the plant population for both okro and cowpea was 10.0 plants per meter square.

2.3 Treatments and Experimental Design

The experimental plots were laid out in a randomized complete block design (RCBD) with seven (7) treatments and replicated three (3) times. The treatments are:

T_0 - Okra with cowpea intercropped at same day of planting
T_1 - Okra with cowpea introduced/interplanted at 1 week after planting
T_2 - Okra with cowpea introduced/interplanted at 2 weeks after planting
T_3 - Okra with cowpea introduced/interplanted at 3 weeks after planting
T_4 - Okra with cowpea introduced/interplanted at 4 weeks after planting
T_5 - Sole okra as control
T_6 - Sole cowpea as control

2.4 Cultural Practices

Weed control was done by applying Glyphosate 360 SL; a foliar acting, systemic, non-selective post-emergence herbicide, at the rate 2.5 L/ha using a knapsack sprayer, a week before planting. Manual weed control by hoeing was done 3 and 6 WAP later. NPK 15:15:15 at 100 kg/ha was applied only to the okra at 3 and 6 WAP. The fertilizer was applied by the side band placement method to ensure efficient use of the fertilizer by the crop.

Super top (a.i. Lambdacyhalothrin 1.5% plus acetamiprid 2% EC), a broad spectrum insecticide was applied at the rate of 25ml/20L water to control insect pests infestation on both okra and cowpea. The spraying to control the flea beetles (*Podagrica sjostedti* Jack) began 7 days after germination and continued on a weekly basis till fruit production. Spraying ended 7 days before the start of harvesting to prevent chemical contamination of the fruits.

2.5 Parameters Measured in Okra and Cowpea

2.5.1 Plant height

The measurement of the plant height began four weeks after planting and continued till flowering in the eighth week. Five plants in the inner rows were tagged and measurement taken on them. A meter rule was used to take the measurement from the ground level to the highest point of the plant. The average plant height was computed for each of the treatments.

2.5.2 Stem diameter

The diameter of the sampled okra plants was taken 10 centimeters from the ground level. The measurement was done at the flowering stage. Vernier caliper was used to take the diameter. The mean for each treatment was recorded.

2.5.3 Number of leaves per plant

The leaves count of okra was done at five weeks after planting (5 WAP) and at the flowering stage (8 WAP). The leaves on the sampled plants for dry matter analysis was counted and recorded. The average for each of the treatments was calculated.

2.5.4 Plant dry matter and crop growth rate

Five plant samples of okra and cowpea from each plot were collected for growth analysis at 5 and 8 WAP of okra. The samples were oven dried at 80°C for 48 hours until a constant weight was recorded. Crop growth rate (CGR) which is an increase in dry matter weight per unit ground area is computed using the formula proposed by [20];

$$CGR = \frac{(W_2 - W_1)}{(T_2 - T_1)}$$

Where W_1 and W_2 are dry weights at times T_1 and T_2 respectively, and expressed as g/m^2/day.

2.5.5 Number of fruits per plant

Five plants from each plot were tagged and number of fruits harvested where cumulatively recorded on each day of harvesting. The mean was calculated and recorded for each treatment.

2.5.6 Fresh fruit yield

Okra was harvested when the tip of the pod snap or break easily when pressed with the fingertip. The fresh fruit of okra was harvested on a four day interval. The cumulative yield per plot for each treatment was calculated and the yield converted to kilogram per hectare.

2.5.7 Nodule count

Five samples of cowpea plants were carefully dug using a shovel. The soil around the root was carefully removed and all nodules collected into a white envelope and sealed and sent to the laboratory for counting.

2.5.8 Grain yield

Grain yield was determined from the entire plot of 4 m x 4 m (16 m^2). This was done at physiological maturity when most of the leaves had turned yellow and about 85% of the pods were brownish. The pods were harvested, sun dried and then threshed. The grains were oven dried for 48 hours at 80°C and weighed. The grain yield was weighed and extrapolated to kg/ha.

2.5.9 Pod length and number of seeds per pod

Twenty pods were randomly selected from each plot and the length measured with a ruler. The mean for each of the treatment on each block was determined. Twenty pods were randomly selected for the determination of seeds per pod. The pods were threshed and their seeds removed, counted and recorded. The number of seeds per pod was calculated as follows:

$$Number of seeds per pod = \frac{total number of seeds counted}{number of pods counted}$$

2.5.10 One hundred-seed weight (g)

One hundred seeds from the threshed and oven dried seeds for each plot were counted and weighed. The means represents the 100-seed weight for each treatment.

2.6 Computation of Competition Indices

2.6.1 Land Equivalent Ratio (LER)

Land Equivalent Ratio (LER) is commonly used to indicate the biological efficiency and yield per unit area of land as compared to mono-cropping system. It was computed using the formula as proposed by Willey [21];

$$LER = \frac{Y_{1,2}}{Y_{1,1}} + \frac{Y_{2,1}}{Y_{2,2}}$$

Where; Y is the crop yield and the suffixes 1 and 2 denote crop 1 and crop 2 in the mixture. Thus $Y_{1,2}$ is the yield of crop 1 when grown in mixture with crop 2 and $Y_{1,1}$ is the yield of crop 1 when grown in monoculture. $Y_{2,1}$ is the yield of crop 2 when grown in mixture with crop 1and $Y_{2,2}$ is the yield of crop 2 when grown in a monoculture. When the LER is greater than one, the intercropping favours the growth and yield of the species. In contrast, when LER is lower than one the intercropping negatively affects the growth and yield of the plants grown in mixtures [22];

2.6.2 Area Time Equivalent Ratio (ATER)

ATER provides a practical way of comparing the yield advantage of intercropping over mono-cropping in reference to time taken by component crops in the intercropping systems (Willey, 1979). ATER was calculated by the formula proposed by Hiebsch [23];

$$ATER = \frac{(RYaXTa) + (RYbXTb)}{T}.$$

Where; RYa = Relative yield of component A in mixture
Ta = duration (in days) of component A
RYb = Relative yield of component species B in mixture
Tb = duration (in days) of component B
T =total duration of the intercropping system (in days).
The interpretation of ATER involves that ATER greater than 1 implies yield advantage;
ATER equal to 1 implies no effect of intercropping;
ATER less than 1 shows yield disadvantages.

2.6.3 Monetary Equivalent Ratio (MER)

Monetary equivalent ratio (MER) helps to determine the economic returns of intercropping compared to sole cropping. The MER was developed by Adetiloye [24]. It was computed by the formula;

$$MER = \frac{r_1 + r_2}{R}$$

Where r_1 and r_2 are monetary returns of component crops in mixture and R is the higher sole crop monetary return compared with the other.

MER value greater than 1 implies economic advantage in intercropping whiles MER value less than implies economic loss. However, MER value of one means no economic advantage as far as intercropping is concerned.

2.7 Statistical Analysis

The data collected were analyzed using the one-way analysis of variance (ANOVA) with the aid of GENSTAT version 11.1 (2008) and the significant treatment means were separated by the least significance difference (LSD) to determine which of the treatments has significance difference or not at 5% probability level.

3. RESULTS AND DISCUSSION

3.1 Plant Height of Okra and Cowpea

Results from Table 1 shows that time of intercropping had significant ($P < 0.05$) effect on okra plant height at 7 and 8 WAP (Table 1). On both occasions, okra plant height when planted on the same day with cowpea (T_0) was significantly lower than all other treatments. Significant difference ($P < 0.05$) was recorded in the plant height of cowpea at 7 WAP. At 50% flowering stage, sole cowpea recorded the highest plant height which was significantly higher than all the treatment except T_0. At one week after planting the initial growth of okra, no significant difference was observed in its height among the various treatments since there was not much competition between okra and cowpea at that stage of growth. Ijoya and Dzer [25] reported that the height of okra planted as a sole crop and that sown in intercrop with maize at different times showed no significant difference at the initial stage.

The growth and demand of cowpea for resources at flowering and podding stages might have influenced the significant differences in the height of okra at the later stages. The difference in the plant height of okra relative to that of cowpea meant that the two crops not only competed for water and nutrient but also for sunlight [26]. The height a plant attains in a mixture determines the extent of interception of light which in turn determines the photosynthetic activities in the leaves. The plant height of okra observed in T_0 and T_1 treatments in relation to its shoot biomass shows visible signs of etiolation which implies that the early introduced cowpea competed greatly with the okra. This observation is consistent with the annual report of Basque Research [27] which stated that plants growing under competing conditions tend to grow taller in an effort to scramble for nutrients around the growth environment and that growth may be in terms of height at the expense of dry matter production.

3.2 Number of Leaves and Stem Diameter

Results from Table 1 shows time of intercropping significantly ($P < 0.05$) influenced the number of okra leaves per plant at 8 weeks. Sole okra at one week after planting recorded the greatest number of leaves which was significantly higher than the other treatments. Significant difference ($P < 0.05$) was also observed in the stem diameter of okra at 50% flowering stage but ($P > 0.05$) not on cowpea. Sole okra recorded the greatest stem diameter which was significantly higher than all treatments except T_4. The number of leaves and stem diameter of sole okra was greater than the intercrop component. There was a gradual increase in number of leaves and stem diameter as the time of introduction of the component cowpea was delayed. This observation agrees with the report of Ijoya and Dzer [25] who in an okra and maize intercropping study observed that the largest number of leaves in okra was observed when maize was planted 4 weeks later into the mixture. The greater the number of leaves, the greater the interception of solar radiation. The differences in biomass production may be attributed to the photosynthetic activities that took place in the plants which were influenced by the number of leaves and the competition for growth resources [28] Intercropping is said to increase the amount of solar radiation intercepted due to larger canopy spread, which led to efficient utilization of light resources [29]

3.3 Nodule Count

In the case of nodule count at 50% flowering stage, significant difference was observed among the treatment means (Table 3). Sole cowpea recorded a greater number of nodules which was significantly higher than T_2, T_3, and T_4. Time of planting cowpea in okra significantly affected the nodule counts. Competition for space, sunlight, nutrient and water by the cowpea with okra greatly influenced the nodule counts. Clearly, cowpea which was introduced early into the okra was not suppressed in growth hence greater nodule number was recorded although lower than the monocrop cowpea. This present study agrees with the work done by Abdul-Rahaman [30] who recorded a decrease in nodule number with delay in intercropping soyabean with maize at the deciduous forest zone of Ghana.

3.4 Dry matter

Finally, significant difference ($p < 0.05$) was observed in the dry matter accumulation and crop performance at different times (5 and 8 wap) (Tables 2 and 3). Sole okra recorded the greatest dry matter and crop growth rate although it was not significantly different from t_4. At 50% flowering stage, the dry matter yield of sole okra was significantly higher than all treatments. The least cgr was observed in t_0. In terms of dry matter yield and cowpea growth rate, significant differences were observed among the treatment means. In both parameters, sole cowpea recorded the greatest dry matter and crop growth rate which was significantly higher than all the treatments except t_0. Dry matter production and crop growth rate of the component crops were affected by the time cowpea was introduced. It was observed that the cowpea which was introduced into the okra at a later date was suppressed in growth. Similar trend was observed in the crop growth rate of cowpea within the 21-day period. The general trend was that as the introduction of cowpea was delayed, the dry matter of okra increased. The shading effect of the component crop which grew taller had a negative effect on the other component in terms of dry matter production. Shading reduces the photosynthetic activity of the component crop hence a suppression of it growth and dry matter production. In this study, the dry matter yield of cowpea decreased with delay in introduction. This observation agrees with the report of Osei-Bonsu and Buckles [10] who in a maize – mucuna intercrop trial noted that the mucuna gave higher dry matter yield 4 wap than 10 wap maize.

3.5 Yield and Yield Parameters of Okra and Cowpea

Pod length differ significantly ($P < 0.05$) among the treatment but seeds per pod was not significant (P > 0.05) (Table 4). Although T_1 recorded the highest pod length, it was not significantly different from all the other treatments except T_4. The number of grains per pod of cowpea was not significantly different among the treatments. This implies that grains per pod are influenced more by the genetic make-up of the cowpea and not by environmental factors. The length of pod decreased with a delay in intercropping which might be due to decrease in photosynthate production. The capacity of the source determines the sink size and ultimately the seed yield. Climpson [31] stated that early intercropped legumes performed better because they had a long period of time without competition to assimilate organic matter to fill their grains. In the work of Hauggaad-Nielsen and Ambus [32] the yield of the legume intercrop was reduced due to late introduction into the cereal. This present study however, contradicts that of Ghaffarzadeh et al. [33] who in a cereal-legume intercrop study observed a decrease in the yield of cereal with late introduction of the legume component. Probably, the difference in the component crops used in the studies as well as environmental conditions might account for this.

Hundred seed weight differ significantly (P < 0.05) among the treatment means. Sole cowpea recorded the greatest 100 seed weight but it was not significantly different from T_0 and T_2 (Table 4).The greatest (P < 0.05) yield of cowpea was recorded in the sole cowpea which was significantly higher than all other treatments, except the T_0 treatment. Among the intercrops, yield of T_0 treatment was greater than those of T_3 and T_4 treatments. The yield from the T_4 treatment was the lowest among all treatments. The greatest yield was produced by the sole okra (4119 kg/ha), which was significantly higher than all other treatments, except T_4 treatment. The least yield was observed in okra sown at the same time with cowpea (T_0). Sole okra recorded a 147.2% yield increase over okra sown at the same time with cowpea (T_0).

There was an inverse relationship between the yields of the component crops in relation to the time of introducing the cowpea into okra. The yield of okra increased with a delay in planting cowpea while the yield of cowpea decreased with delay in interplanting into okra. The increase in the yield of okra with delay in time of introduction of the cowpea may be attributed to less competition it suffered from the cowpea. On the other hand, the gradual reduction in the yield of cowpea with delay in its time of introduction into the okra may be attributed to the intense competition it suffered from the okra for growth resources such as nutrient, light, space and water [34].

Number of fruits per plant is a function of the fresh fruit yield of okra. The number of fruits per plant of okra had a direct relationship with the overall yield. The reduction in the number of pods per plant of intercropped okra compared with the sole okra is in line with the report made by Seran and Jeyakumaran [35] that the number of pods per Capsicum plant was lower in capsicum-cowpea intercropping compared with monocropping. Competition for growth resources such as space, water, nutrient may account for this.

3.6 land Equivalent Ratio and Area Time Equivalent Ratio (LER and ATER)

The results of time of introduction of cowpea on ler and ater are shown in Table 5. Significant (p < 0.05) differences were observed in the ater as well as ler values. The ler and ater values for each of the intercrop treatment were greater than 1.00 which indicates yield advantage over sole cropping. One way of assessing the benefit of intercropping is through the use of land equivalent ratio (ler). This index measures both the beneficial and negative interactions between the crops. The results of the present study showed that the ler values for all the treatments showed yield advantages of intercropping above monocropping. This finding confirms the work done by Sarkodie-Addo and Abdul-Rahaman [36] who in a maize-soybean intercropping study recorded yield advantages over the sole crops. The highest ler was recorded in okra intercropped with cowpea two weeks later (t_2). This finding however, contradicts that of Ijoya and Dzer [25] who reported that okra sown at the same time with maize recorded the highest ler. The only plausible explanation for this may be due to differences in environment as well as the crop species since their requirement for growth resources differ. Since the duration of the component crops on the field varied with time, area time equivalent ratio (ater) was computed and compared. The results showed yield advantages in all intercropping times. The reduction in the ater values compared to the ler values might be due to the fact that the intercrops spent more time on the field than that of the sole crop.

Table 1. Yield and yield parameters of okra

Treatment	Plant height (cm)			Number of leaves stage (8 WAP)	Stem diameter (cm)
	6 WAP	7 WAP	8 WAP		
T_0	20.70	37.6	0.80	22.50	0.90
T_1	24.50	37.8	0.60	23.90	1.09
T_2	41.10	86.5	2.20	25.90	1.28
T_3	41.60	93.9	2.50	27.90	1.23
T_4	52.70	137.9	4.10	30.70	1.44
T_5	53.30	167.3	5.40	35.00	1.65
Grand mean	39.00	93.5	2.60	27.60	1.26
LSD (5%)	2.10	6.4	0.30	1.50	0.25
CV (%)	6.60	8.4	13.60	6.60	10.60

T_0 - Okra with cowpea intercropped at same day of planting; ;T_1 - Okra with cowpea introduced/interplanted at 1 week after planting; T_2 - Okra with cowpea introduced/interplanted at 2 weeks after planting; T_3 - Okra with cowpea introduced/interplanted at 3 weeks after planting; T_4 - Okra with cowpea introduced/interplanted at 4 weeks after planting and T_5 - Sole okra as control.

Table 2. Yield and yield parameters of okra

Treatment	Dry matter yield (g/ m^2)		CGR (g/m^2/day)	No. of fruits per plant	Fresh fruit yield (kg/ha)
	5 WAP	8 WAP			
T_0	20.70	37.6	0.80	1.51	1666.0
T_1	24.50	37.8	0.60	3.67	2523.0
T_2	41.10	86.5	2.20	5.02	3767.0
T_3	41.60	93.9	2.50	5.91	3865.0
T_4	52.70	137.9	4.10	7.91	3998.0
T_5	53.30	167.3	5.40	8.27	4119.0
Grand mean	39.00	93.5	2.60	5.25	3323.3
LSD (5%)	2.10	6.4	0.30	1.21	202.63
CV (%)	6.60	8.4	13.60	12.63	7.47

T_0 - Okra with cowpea intercropped at same day of planting; ;T_1 - Okra with cowpea introduced/interplanted at 1 week after planting; T_2 - Okra with cowpea introduced/interplanted at 2 weeks after planting; T_3 - Okra with cowpea introduced/interplanted at 3 weeks after planting; T_4 - Okra with cowpea introduced/interplanted at 4 weeks after planting and T_5 - Sole okra as control.

Table 3. Growth parameters of cowpea

Treatment	Plant height at 50% flowering (7 WAP) (cm)	Nodule count/plant at 50% flowering stage	Dry matter yield (g/ m^2)		CGR (g/m^2/day)
			4 WAP	7 WAP	
T_0	52.10	23.60	44.20	198.00	7.40
T_1	50.33	24.50	42.40	162.60	5.70
T_2	47.98	19.80	34.20	152.80	5.60
T_3	46.73	19.60	22.10	123.20	4.80
T_4	38.07	10.00	21.80	97.60	3.60
T_6	52.90	25.00	75.40	334.20	12.30
Grand mean	48.02	20.40	40.00	178.20	6.60
LSD (5%)	1.18	4.90	3.10	6.80	0.30
CV (%)	13.5	9.30	9.60	4.70	4.80

T_0 - Okra with cowpea intercropped at same day of planting; ;T_1 - Okra with cowpea introduced/interplanted at 1 week after planting; T_2 - Okra with cowpea introduced/interplanted at 2 weeks after planting; T_3 - Okra with cowpea introduced/interplanted at 3 weeks after planting; T_4 - Okra with cowpea introduced/interplanted at 4 weeks after planting and T_6 - Sole cowpea as control.

Table 4. Yield and yield parameters of cowpea

Treatment	Pod length (cm)	No. of grains per pod	100-grain weight (g)	Yield (kg/ha)
T_0	16.42	16.20	13.60	732.70
T_1	17.00	16.00	13.10	694.00
T_2	16.90	15.10	13.50	669.00
T_3	16.30	16.30	13.00	584.00
T_4	14.80	15.80	12.50	248.00
T_6	16.50	16.50	13.80	822.00
Grand mean	16.30	16.00	13.30	625.10
LSD (5%)	2.10	NS	0.30	95.60
CV (%)	7.10	7.80	1.40	8.40

T_0 - Okra with cowpea intercropped at same day of planting; ;T_1 - Okra with cowpea introduced/interplanted at 1 week after planting; T_2 - Okra with cowpea introduced/interplanted at 2 weeks after planting; T_3 - Okra with cowpea introduced/interplanted at 3 weeks after planting; T_4 - Okra with cowpea introduced/interplanted at 4 weeks after planting and T_6 - Sole cowpea as control.

Table 5. Effect of intercropping on competition indices of okra and cowpea

Treatment	LER	ATER	GMR (GH₵)	MER
T_0	1.29	1.16	4,510.30	0.84
T_1	1.45	1.30	5,501.10	1.02
T_2	1.73	1.57	7,039.40	1.31
T_3	1.64	1.38	6,893.70	1.28
T_4	1.28	1.02	5,991.40	1.12
T_5	1.00	1.00	5,355.10	1.00
T_6	1.00	1.00	2,632.50	0.49
Grand mean	1.34	1.21	5,417.70	1.01
LSD (5%)	0.18	0.15	701.93	0.13
CV (%)	7.33	7.22	7.28	7.29

Ler = land equivalent ratio, ATER = area time equivalent ratio, GMR = gross monetary returns, MER = monetary equivalent ratio okra and cowpea were at prevailing market price of gh₵1.3/kg and gh₵2.2/kg respectively in september, 2017. T_0 - Okra with cowpea intercropped at same day of planting; T_1 - Okra with cowpea introduced/interplanted at 1 week after planting; T_2 - Okra with cowpea introduced/interplanted at 2 weeks after planting; T_3 - Okra with cowpea introduced/interplanted at 3 weeks after planting; T_4 - Okra with cowpea introduced/interplanted at 4 weeks after planting; T_5 - Sole okro as control and T_6 - sole cowpea as control.

3.7 Gross Monetary Returns (GMR) and Monetary Equivalent Ratio (MER)/ha

Significant difference ($P < 0.05$) was observed in gross monetary returns of okra and cowpea intercrop compared to it component sole cropping per the same unit area of land as shown in Table 5. Intercropping okra with cowpea at two weeks recorded the highest gross monetary returns of GH¢ 7,039.40 followed by okra intercropped with cowpea at three weeks. Intercropping okra with cowpea at 1, 2, 3 and 4 WAP okra was seen to be higher than the highest sole crop i.e. okra. However, the gross monetary returns of okra intercropped with cowpea the same day was lower than its component sole okra. There was significant difference ($P < 0.05$) among the MER of the various treatments. All the intercropping periods showed MER values greater than one except T_0. The greatest MER was observed in T_2 which was 1.31. The gross monetary return as well as monetary equivalent ratio showed higher economic returns in intercropping compared with sole cropping except in the case of T_0 which the MER was below one. This disadvantage in intercropping agrees with work done by Dhima et al. [37] who found the economic returns in intercropping lower than sole cropping due to reduction in yield of component crops. The higher economic returns in intercropping okra and cowpea might be due to better utilization of resources between the component crops. Ghosh [26] found that the greater LER, the higher the economic returns.

4. CONCLUSION

From the results obtained, it can be concluded that intercropping okra with cowpea is a beneficial cropping system since the LER and ATER computed were all above 1. To ensure higher yield and monetary returns, cowpea should be interplanted two or three weeks after planting okra. It is however recommended that further investigations be done to evaluate a wider range of okra and cowpea varieties under various planting distances and spatial arrangements.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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